Vertically resolved aerosol optical properties over the ARM SGP site

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SUMMARY

We will present an overview of early airborne results obtained aboard the Center for Interdisciplinary Remotely-Piloted Aircraft Studies (CIRPAS) Twin Otter aircraft during the Atmospheric Radiation Measurement (ARM) program aerosol intensive observation period in May 2003.

Keywords: Aerosol optical properties, scattering, absorption, extinction, size distribution, radiation

EXTENDED ABSTRACT

In order to meet one of its goals – to relate observations of radiative fluxes and radiances to the atmospheric composition – the Department of Energy's Atmospheric Radiation Measurement (ARM) program has pursued measurements and modeling activities that attempt to determine how aerosols impact atmospheric radiative transfer, both directly and indirectly. However, significant discrepancies between aerosol properties measured in situ or remotely remain. We would like to give two examples:

i) Since March 2000, ARM has been measuring in situ aerosol profiles (IAP) by performing routine flights with a light aircraft (Cessna C-172N) over the heavily instrumented Southern Great Plains (SGP) site in Oklahoma. The IAP plane utilizes a similar aerosol instrument package to the one operated continuously at the SGP ground site. However the IAP plane has a limited ceiling, measures the aerosol at a relative humidity of 40% rather than at ambient RH, and the inlet allows particles to pass only if their aerodynamic diameter is <1µm. Even after attempting (altitude-independent) corrections for all these limitations (using information from ground-based nephelometers and raman lidar) an analysis performed by *Andrews et al.*[1]shows that those measurements do not account for <u>all</u> of the aerosol extinction: The IAP-derived aerosol optical depths are consistently less (0.05 or ~30%) than the aerosol optical depths (AOD) measured on the ground by sunphotometers. We have assessed the accuracy of ground-based AOD measurements made by ARM sunphotometers (Cimel, MFRSR, and RSS) during two intensive observation periods (IOPs) by comparing to an instrument (AATS-6) that was calibrated at Mauna Loa immediately before or after the IOPs, Hawaii. In both IOPs, we found that the sunphotometer-measured AODs agree within 0.02 (rms, absolute AOD value)[2,3]. Hence, the mean AOD

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difference of 0.05 found between light aircraft and ground-based sunphotometers is significant. In other words, extinction closure has not been achieved. A similar discrepancy was found when comparing the IAP extinction with extinction from the ground-based Raman lidar at the SGP site (i.e. IAP extinction 30% lower than Raman, *Ferrare et al.*,[4]). It should be mentioned that the light aircraft package was aimed at studying vertical aerosol variability and was not optimized for extinction closure (*J. Ogren, personal communication*).

ii) *Mlawer et al.*[5] successfully modeled ground-based measurements of direct and diffuse solar irradiance from the Rotating Shadowband Spectroradiometer (RSS, *Harrison et al.*,[6]) at the SGP site. They used well-validated AOD and water vapor measurements[2,7] as input. However in order to minimize the residuals between measurements and model, *Mlawer et al.*[5] had to assume aerosol single scattering albedos ω_0 that are "much lower than usually assumed in the aerosol community for this location, and [which] present an intriguing puzzle for this community to consider". *Mlawer et al.*[5] analyzed three cases for September/October 1997 and found ω_0=0.89,0.9, and 0.67 (assumed spectrally-invariant). More recently, *Sheridan et al.*[8] published their 4-year record (1996-2000) of ground-based aerosol measurements at the SGP site. They find a median value of ω_0=0.95 (λ=550 nm, ambient RH), but in September/October 1997 values as low as ω_0=0.87 occur on occasion (but not 0.67 as needed for one case by *Mlawer et al.*[5]). A very similar discrepancy was found applying the same methodology to a larger data set.[9]

Based on results like the ones just mentioned, the ARM Aerosol Working Group recommended additional measurements and modeling studies to accurately address the impact of aerosols on atmospheric radiative transfer. To this end the ARM program has funded two Aerosol IOPs: A mini-IOP focusing on aerosol absorption under controlled conditions (carried out at the Desert Research Institute, Reno, NV in Summer 2002) and an IOP with an airborne and ground-based component at the SGP site conducted in May 2003. The airborne component involves two aircraft: the IAP aircraft mentioned above and the Center for Interdisciplinary Remotely-Piloted Aircraft Studies (CIRPAS) Twin Otter aircraft.

We will give an overview of early airborne results obtained aboard the CIRPAS Twin Otter. The aircraft will carry instrumentation to perform in-situ measurements of aerosol absorption, scattering, extinction and particle size including such novel techniques as the photoacoustic and cavity ring-down methods. Aerosol optical depth and extinction will be measured with the NASA Ames Airborne Tracking 14-channel sunphotometer. Furthermore up- and downwelling solar (broadband and spectral) and infrared radiation will be measured using three different instruments. The up-looking radiation instruments will be mounted on a newly developed stabilized platform, which will keep the instruments level up to aircraft pitch and roll angles of 10°. Our analysis will focus on several areas:

Aerosol extinction closure. Extinction closure studies can be viewed as addressing the question: "Can in situ measurements of aerosol properties account for the solar beam attenuation by an aerosol layer or column." Hence we will compare extinction measurements performed by the in-situ instruments to extinction profiles obtained from vertically differentiating aerosol optical depth profiles measured with the Ames Airborne Tracking 14-channel Sunphotometer, AATS-14.[10]

Aerosol absorption closure: We will compare in-situ measurements of absorption to absorption derived from radiative flux divergence across an aerosol layer.[11,12]

Additional effort will be directed toward measurement of cloud condensation nucleus concentration as a function of supersaturation and relating CCN concentration to aerosol composition and size distribution. This relation is central to description of the aerosol indirect effect.

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